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	Patents ADP number *(if you know it)*	765221700l
	If the applicant is a corporate body, give the country/state of its incorporation	Finland
4.	Title of the invention	A GPS Device
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DUPLICATE

A GPS Device

Field of the Invention

The present invention relates to a timing synchronisation receiving method, in particular but not exclusively for use in a communications system for synchronising a location signal in a cellular wireless system.

Background of the Invention

Wireless cellular communication networks and their operation are generally well known. In such a system the area covered by the network is divided into cells. Each cell is provided with a base station, which is arranged to communicate with a plurality of mobile stations or other user equipment in a cell associated with the base station.

In these known systems, it is possible to locate a mobile station with reference to a base station, and therefore possible to locate a mobile station within the operational transmission range of a base station.

As is also known additional location information can be determined by measuring the time between transmission and reception of a signal between a mobile station and a known base station or transmitter. Using such time of arrival (TOA) methods with signals transmitted from base stations it is possible to locate a mobile station within tens of metres.

Using the base station to transmit timing signals and using these signals to determine a positional estimate produces an

estimate containing several potential errors and problems One of the major problems is the many different paths that the transmissions from the base station to the mobile station can take. The path can be direct, which provides an accurate estimation of the distance between the base and mobile stations or the path can be diffracted or reflected by man-made or natural phenomena such as buildings, large vehicles and hills. These indirect paths do not reflect the true distance between the base station and the mobile station and therefore produce location estimation errors. These diffracted and reflected signal paths occur more frequently in built-up and urban environments, thus degrading the more accurate base station location estimations due to the increased density of base stations.

A separate development in location estimation has been the development of a global positioning satellite (GPS) system which enables a GPS receiver to accurately locate its position within a couple of metres by measuring the time differences between received signals from satellites orbiting the earth. The GPS system relies on both the transmitter (the orbiting satellites) and the receiver to have accurate knowledge of a transmitted timing sequence signal in order that an accurate estimation of the position of the receiver can be made.

As is known in the art the GPS orbiting satellites are accurately synchronised each carrying an accurate very stable atomic clock. Furthermore the constellation of satellites are monitored from controlling ground stations and any timing errors detected are effectively corrected.

As the cost of supplying each GPS receiver with an accurate and stable clock oscillator such as an atomic clock is prohibitive, the typical GPS receiver determines an accurate GPS time sequence by comparing at least four separate GPS timing signals received from at least four different satellites. These satellites are used to both accurately synchronise the receiver clock and to provide an accurate estimation of the location of the signal.

The process of locating four of these timing sequences and fixing accurately the receiver clock is performed by a timing synchronisation sequence.

As it is known in the art a timing synchronisation sequence can be carried out by receiving the Time of Week (ToW) signal transmitted by each GPS satellite. The ToW signal is transmitted once per GPS subframe, in other words exactly every six seconds. The detection of the ToW signal is largely dependent on the received strength of the signal, and below a certain threshold it becomes impossible to decode the information bits that go to make up the ToW signal. Additionally, processing the ToW signal takes up a significant amount of processing time which has an adverse impact on power consumption.

As is further known in the art, cellular mobile stations may be equipped with GPS receiver modules in order to improve the location estimation capacity of the mobile station.

The mobile station by itself is too inaccurate to perform the role of a GPS clock. With incremental errors of the order of several parts per million, and by not being synchronised to the GPS satellite clocks the uncorrected

positional and timing errors would on average produce highly inaccurate positional values. Furthermore an inaccurate mobile station clock would also reduce the likelihood of acquiring the GPS signals in the first place

On the other hand constantly performing a timing synchronisation sequence on the received GPS system timing sequences is equally problematic. As explained earlier each of these timing synchronisation sequences consume both processing power and battery power. Thus the mobile station battery would be rapidly drained by performing constant timing synchronisation sequences. In any event, the mobile station may not be able to receive the GPS signals with sufficient strength to extract the timing information.

US patent 5,945,944 describes a combined GPS receiver and mobile station transceiver, wherein the GPS timing information is determined by signals received from the base station, which is then transmitted via a communications link to be processed by a separate base unit. The positional estimate of the mobile station not immediately available to the mobile station.

US patent 6,346,911 describes a method of determining GPS time by capturing GPS data and locating a predetermined code sequence within the captured GPS data and the time difference between the captured data start and the start of the located predetermined code.

US patent 6,150,980 describes a method of determining the time for a GPS receiver. Timing signals derived from a communication system are received by a GPS receiver and decoded to provide accurate time information.

Summary of the Invention

It is an aim of the embodiments of the present invention to address or partially mitigate one of the more of the problems discussed previously.

There is provivided according to a first aspect of the present invention a GPS device comprising: a first circuit arranged to receive at least one first signal and arranged to output first timing information dependent on said first signal; a second circuit arranged to receive at least one second signal and arranged to output second timing information dependent of said second signal; and a third circuit arranged to determine timing information of said device, said third circuit arranged to receive at least one of said first and second timing information, and further arranged to produce third timing information dependent on at least one of said first and second signals, wherein said third circuit further is arranged to produce a location estimate dependent on said first and third timing information; and wherein said third timing information is initially synchronised to said first timing information and maintained substantially synchronised to said at least one first signal using said second timing information.

The first signal may comprise a Global Positioning Satellite system signal.

The second signal may comprise a cellular network control or communications signal.

The first timing information may comprise at least one of: a demodulated Global Positioning Satellite system time; at least one Global Positioning Satellite system pseudo-range; a demodulated Global Positioning Satellite system timing data word.

The second timing information may comprise at least one of: cellular network base station symbol timing; cellular network base station frame timing.

The first circuit may comprise a Global Positioning Satellite receiver.

The second circuit may comprise a cellular network receiver.

The third circuit may comprise: a GPS demodulator; a timing estimator; a location estimator; and a clock register.

The first circuit may further comprise: a GPS demodulator; and a timing estimator.

The third circuit may comprise: a location estimator and a clock register.

The third circuit may comprise a cellular reference clock and wherein said third timing information may be further maintained substantially synchronised to said at least one first signal using said cellular reference clock.

The second and third circuit may be implemented in a single circuit.

The device may further comprise a threshold circuit arranged to further substantially synchronise said third timing information to said at least one first signal dependent on a threshold event.

The threshold circuit may be arranged to further substantially synchronise said third timing information using said first timing information.

The threshold event may comprise at least one of: a time period; a movement of said device out of a building; a movement of said device following a period of relative static nature; a determined number of base station handovers; a received first signal strength threshold; a number of received first signals.

A integrated circuit may comprise a GPS device.

The clock register may comprise random access memory.

According to a second embodiment of the present invention there is provided a method for determining the position of a device using GPS comprising: receiving at least one first signal; producing first timing information dependent on said at least one first signal; receiving at least one second signal; producing second timing information dependent on said at least one second signal; producing third timing information dependent on said at least one of said first and second timing information; initially synchronising said third timing information to said first signal and maintaining synchronisation to said first signal using said second timing information, and determining a location of said device dependent on said first timing information and

said third timing information, wherein said determining step comprises the step of calculating a difference between said third timing information and said first timing information to determine location estimates.

The step of receiving at least one first signal may comprise; receiving at least four GPS signals.

The step of producing at least one first timing information may further comprise; processing said at least four received GPS signals to determine at least four GPS timing signals; processing said at least four GPS timing signals to produce a true GPS timing signal.

The step of receiving at least one second signal may comprise; receiving at least one communications or control signal from a wireless cellular communications system base station.

The step of producing said third timing information may comprises a further step of triggering a threshold circuit arranged to further substantially synchronise said third timing information to said at least one first signal dependent on a threshold event.

The further step of triggering said threshold circuit may be arranged to further substantially synchronise said third timing information using said first timing information.

The step of triggering said threshold circuit may further comprise the detection of a threshold event, possibly comprising at least one of: a time period; a movement of said device out of a building; a movement of said device

following a period of relative static nature; a determined number of base station handovers; a received first signal strength threshold; a number of received first signals.

Brief description of Drawings

For a better understanding of the present invention and how the same may be carried into effect, reference will now be made by way of example only to the accompanying drawings in which:

Figure 1 shows a schematic view of a typical cell layout of a cellular network, in which embodiments of the present invention can be implemented;

Figure 2 shows a schematic view of a Global Positional Satellite (GPS) system, in which embodiments of the present invention can be implemented;

Figure 3 shows a schematic view of the GPS transmitted bit timings and the associated gold code sequence timings;

Figure 4 shows a series of GPS location estimate arcs and error arcs illustrating the GPS system as shown in Figure 2;

Figure 5 shows a schematic view of a first embodiment of the present invention incorporated in a mobile station wireless communication transceiver operating within a cellular network as shown in figure 1; and

Figure 6 shows a schematic view of a second embodiment of the present invention incorporated in a mobile station

wireless communication transceiver operating within a cellular network as shown in figure 1;

Figure 7 shows a schematic view of a third embodiment of the present invention incorporated in a mobile station wireless communications transceiver operating within a cellular network as shown in figure 1;

Figure 8 shows a flow diagram view of the method used in the third embodiment of the present invention as shown in figure 7.

Detailed Description of Embodiments

Reference is made to Figure 1, which shows part of a cellular telecommunications network 51 in which embodiments of the present invention can be implemented. The area covered by the network is divided into a plurality of cells 1, 9. Figure 1 shows a central cell 1 surrounded by six partial cells 9. Further cells bordering these cells are not shown for clarity. Each cell has associated therewith a base transceiver station 3 also known as a base station. The base station 3 is arranged to communicate with mobile devices or other user equipment 5 associated with the base station 3. Examples of mobile devices include mobile telephones, personal digital assistants (PDA) with transceiver capabilities, and laptops with transceiver capabilities. These mobile devices 5 are also known as mobile stations.

The cells may overlap at least partially or totally. In some systems, these cells may have a different shape to that illustrated. In some embodiments the base stations 3 may communicate with mobile devices 5 outside their associated

cell. In other embodiments mobile devices 5 may communicate with mobile devices 5 directly and without recourse to the base station 3. In other embodiments of the invention base station 3 may communicate with another base station 3 directly.

Communication between the mobile station 5 and the base station 3 within a cell is synchronised to both the symbols and frames transmitted by the base station 3. As in known in the art the base station 3 derives its timing from a clock accurate and stable to within a fraction of a part per million. The mobile station 5 receives the base station signals and uses the base station signals to synchronise its own internal clock and timings.

As is known in the art, code division multiple access (CDMA) network standards used in the United States are synchronised with the GPS timing sequence, other communication standards such as the global system for mobile communications (GSM) and wideband code division multiple access (WCDMA) do not provide a base station timing synchronised to GPS time, and are therefore considered to be asynchronous with respect to GPS time. Furthermore the base stations and their timing can be considered to be asynchronous to one another.

Figure 2 shows a schematic view of a typical GPS system. A GPS receiver or mobile station 5 uses an antenna to receive signals 103 from orbiting satellites 101. In Figure 2 the mobile station 5 can "see" four of the constellation of orbiting satellites 101(a), 101(b), 101(c), 101(d). Each of the satellites transmits signals 103(a), 103(b), 103(c), 103(d).

These signals are made up of subframes. Each subframe comprises a 50 bit per second data sequence. This 50 bit per second data sequence comprises a known preamble, a Time of Week (ToW), and a Subframe ID. The preamble is a predetermined eight bit identifier at the beginning of every subframe, and a two bit (00) sequence at the end of every subframe, which is the same for all of the satellites. The Time of Week signal is a seventeen bit sequence which accurately defines the time of the start of the current subframe.

In order that this signal is capable of being received at very low power levels and still be extracted from the background noise the data sequence is modulated using a known pseudorandom timing sequence. This pseudorandom sequence also known as the gold code is 1023 bits long and is transmitted at 1.023Mhz, in other words the code sequence repeats 20 times per data bit. As this higher frequency signal is coherent with the data bit stream it can be possible to produce an accurate timing estimate, and hence positional estimate, if one is able to identify/ detect the start of a bit edge, and in addition one knows exactly to which bit within the data bit sequence the detected edge belongs. This requires the receiver to 'know' true GPS time to within +/- 1/2 a bit period, i.e. within +/- 10ms and preferably (for maximum performance and fastest time to fix) within +/- 1/2 a gold code sequence i.e. +/- 500μs.

The detection of a bit edge requires a lower received signal level than the signal level required to decode the signal, and merely requires that the synchronisation to the gold code sequence is found. This can be carried out by examining the result of a correlation with the received signal and the

gold code sequence. Where two sequential bits have differing values, i.e. the first bit has a '1' value and the second bit a '0' value or vice versa the result of the correlation will suddenly change value at the bit edge passes. As the bit edge and the gold code sequence edge are coherent at this point the determination of the bit edge allows the determination of the gold code sequence edge.

The timing of these edges can be seen with reference to figure 3. Figure 3 shows a sequence of GPS bits 201, the bits shown are the three sequential bits x-1 203, x 205, x+1 207 and a further bit y 208. Each bit according to the known art is 20ms long. The minimum required time accuracy window 215 is shown straddling the x-1'th 203, and x'th 205 bits and is formed from a 1/2 bit period 211, from the middle of the x-1'th bit to the edge of the x-1'th bit, and a 1/2 bit period 213 from the start of the x'th bit to the middle of the x'th bit.

Figure 3 further shows a simplified view of the gold code alongside the GPS signal. For simplicity only the timings of the gold code sequences for the x-1'th and x'th bit are shown. The x-1'th bit gold code timings for the first, penultimate and last gold code sequences are shown, these being G/C-1 217, G/C-19 219, and G/C-20 221. The x'th bit gold code timings for the first, second and last gold code sequences are also shown, these being G/C-1 223, G/C-2 225, G/C-20 227. The x'th bit first gold code sequence follows immediately after the x-1'th bit last gold code sequence. The optimum time accuracy window 233 is formed from a 1/2 gold code sequence time period 229, from the middle of the x-1'th bit G/C-20 sequence to the edge of the x-1'th bit G/C-20 sequence, and a 1/2 gold code sequence time period

231 from the start of the x'th bit G/C-1 sequence to the middle of the x'th bit G/C-1 sequence.

The knowledge of exactly to which bit within the data bit sequence the detected edge belongs to can be determined using knowledge of the GPS system. As is known in the art it is possible to use the GPS almanac in order to determine at any specific time where the GPS satellites are currently located and therefore the approximate time delay of the received bit within the +/- 10ms limit. So using a rough GPS time value and knowledge of the location of the GPS satellites it is possible to determine that the received bits from each of the GPS satellites are specific received bits.

The location estimate of the mobile station using the typical GPS system is carried out using a process known as triangulation. This process assumes that a time signal stored by the mobile station 5 and the orbiting satellite 101 is accurately synchronised. The pseudorandom timing sequence is transmitted repeatedly from the satellite 101 and received by the mobile station 5. The mobile station 5 then compares the received sequence against the expected sequence in order to determine a timing delay. Using this timing delay and the accurately known position of the satellite, the mobile station estimate prescribes an spherical arc along which the mobile station is estimated to be. It is the combination of these arcs that provide an accurate positional estimate. If three satellites can be "seen", providing the estimation system is functioning, the three arcs intersect at two points. If four or more satellites are "seen" then the arcs intersect at a single

location - providing a single positional estimate in three dimensional space.

Figure 4 shows a simplified 2-dimensional schematic view of an ideal situation where three estimated arcs 201(a), 201(b) and 201(c) intersect at a single point 203 indicating a single accurate positional location of the mobile station 5.

As the mobile station internal time is typically accurate to less than several parts per million the synchronisation between the mobile station 5 timing and the satellite 101 timing drifts. In such a situation the estimated arcs do not accurately intersect. Two examples of the effects of a timing error are shown in figure 3, the first where the estimated location arcs 211(a), 211(b), 211(c) create an error in the form of an overlapping region of estimates within which the mobile station may be located 205. The second example of a timing error shown in figure 3 shows where the estimated location arcs 221(a), 221(b), 221(c) describe non-overlapping arcs.

As the synchronisation error is almost entirely due to the instability of the mobile station 5 clock relative to the orbiting satellite 101 clocks, the error is the same for each of the location estimates.

Therefore providing the present invention can receive signals from at least four GPS satellites this synchronisation error can be cancelled out.

The timing synchronisation sequence is not an instantaneous process as discussed above, and is dependent on the signal

strength received from the GPS satellite being strong enough so that the necessary information can be extracted.

Figure 5 shows a schematic view of a first embodiment of the present invention. The mobile station 5 comprises an antenna 301, a GPS receiver 303, a cellular transceiver 305, a radio frequency (RF) interconnect 307, and an interconnect 309.

The antenna 301 is connected to the GPS receiver 303 via the radio frequency (RF) interconnect 367. An interconnect 309 connects the GPS receiver 303 to the cellular transceiver 305.

Furthermore the cellular transceiver 305 comprises a GPS demodulator 313, a timing sequence estimator 325, a location estimator 319, and a clock register 323. The cellular transceiver 305 further comprises interconnects 315, 317 and 321.

The GPS demodulator 313 is connected to the GPS receiver by the interconnect 309. The GPS demodulator 313 is further connected to the timing estimator 325 via the interconnect 315. The timing estimator 325 is connected to the location estimator 319 via the interconnect 317. The timing estimator is further connected to the clock register 323 via the interconnect 321.

Further embodiments can store a timing value in a Random Access Memory (RAM) instead of a clock register. Further embodiments of the invention may implement the functionality of the described components of the system processor within a processor unit and associated memory storing data and functional element instructions.

Mobile station 5 can further comprise other components in order that it performs its purpose as a mobile communications station. The components not directly concerned with the embodiment of the present invention as described are not marked in figure 4 nor described below.

The antenna 301 comprises a multi-bandwidth transceiving antenna, capable of receiving and transmitting cellular network frequency components, and receiving GPS signals transmitted by satellites 101. These received signals are passed to the GPS receiver 303. These received signals are also passed to the cellular transceiver 305 via the GPS receiver 367.

In further embodiments more than one antenna is used to receive the GPS and cellular signals. Further embodiments can have one or more antennas connected to the cellular receiver 305 and one or more antennas connected to the GPS receiver 303. Further in some embodiments at least one antenna is only connected to the cellular transceiver 305 and at least one antenna is only connected to the GPS receiver 303.

The GPS receiver 303 receives GPS radio frequency signal components, and outputs GPS data to the cellular transceiver 305 via the interconnect 309. In a first embodiment of the present invention the GPS data output to the cellular transceiver 305 is the received GPS signals. In other embodiments of the present invention a sample of the GPS signal is output to the cellular transceiver 305 from which timing information can be derived.

The GPS demodulator 313 within the cellular transceiver 305 receives the GPS data output by the GPS receiver and demodulates this data to produce the data stream used by the timing estimator to produce an accurate local timing value.

The GPS timing estimator 325 then receives this data from the GPS demodulator 313 in order to determine a corrected local mobile station 5 time substantially synchronised to the GPS satellite time.

Thus following a power up or reset, the mobile station 5 acquires or synchronises its clock register 309 value in order that it is synchronised to the GPS timing signal.

If the mobile station can receive at least four signals mobile station timing can be synchronised to the satellite timing by either receiving the ToW signal from the 50 bit/second data stream, by performing a correlation analysis on the gold code sequence, or by detecting a bit edge in a manner described previously.

In a further embodiment of the present invention the mobile station and satellite timing can be synchronised using data from a single satellite where the position of the mobile station is already defined (within 300m). This predetermination of the location to within 300m can be carried out from determining the position of the current cell from which the mobile station is operating in.

In further embodiments of the present invention the GPS timing estimator 325 may further receive a numeric value from the clock register 323 and output an error value to correct the clock register value 323.

The location estimator 319 shown schematically can now carry out the process of providing an accurate location estimate without the need to perform constant timing synchronisations.

The cellular transceiver 305 also receives radio frequency signal related to the cellular network via the antenna 301. The cellular transceiver 305 uses the radio frequency signals related to the cellular network to derive timing information from the symbol and frame timing information.

Once the mobile station 5 has been reset or switched on, the cellular transceiver 305 receives this timing information in the form of signals received from the base station. These signals can be demodulated and used by the cellular transceiver 305.

In a further embodiment of the present invention on reset or power up of the mobile station 5, an initial GPS timing synchronisation message is received by the cellular transceiver 305. This timing signal is demodulated and passed to the timing estimator 325. The timing signal value is then stored in the clock register 309.

Thus following the initialisation step the GPS timing estimator is not required to perform constant synchronisation between the GPS satellites 101 and the mobile station 5 timing. The GPS timing signals are passed to the location estimator 319 to perform location estimates when required.

The mobile station 5 timing as stored in the clock register 323 is therefore kept updated by deriving timing information from the transmitted communication channel between the base station 3 and the mobile station 5.

The cellular transceiver 305 synchronises its timing with the use of the base station control channel clock. The cellular transceiver 305 uses these synchronised timing signals to increment the clock register value 323 to substantially maintain GPS clock synchronisation.

As the base station timing signal transmitted is accurate to a fraction of a part per million the copy of the GPS timing sequence stored in the mobile station maintained by the base station timing information is accurate enough to produce accurate location estimates, and acquire the GPS signal accurately for several hours without further adjustment.

In further embodiments of the present invention the location estimator 317 receives a further input from the GPS timing sequence estimator. In this further embodiment the location estimator 317 may select either the numeric value of the clock register 309 or the timing value provided from the GPS timing sequence estimator 315 to compare against the received timing signals from the GPS receiver 303 (as at least one GPS satellite time) in order to provide a location estimate.

In further embodiments of the invention the clock register is kept updated by the auxiliary use of a local cellular reference clock (not shown). The local cellular reference clock comprises means for producing a relatively stable oscillation. In some embodiments of the present invention

the local oscillator comprises an accurately tuned crystal clock pulse generator.

In some embodiments of the present invention when the base station 3 timing signal is not received by the cellular transceiver, for instance where the mobile station 5 passes between base stations or is outside of base station range the cellular reference clock can be used to increment the clock register 323 value.

Although the accuracy and stability of the cellular reference clock is not as accurate as the base station clock signal, the cellular reference clock can prevent synchronisation being lost completely.

In embodiments of the present invention the mobile station is not required to be actively communicating on a communications channel. The mobile station can observe the paging or control channel timing signals transmitted from the base station in order to acquire accurate timing information.

Furthermore in other embodiments of the present invention any timing differences between different base station clocks are determined by the timing estimator 325. A mobile station 5 as it moves from one cell to another, requires a process known as handover. As each cell is controlled by a separate base station, the timing estimator 325 can apply timing adjustments to the mobile station clock register 323 in order to compensate for timing differences between base stations as the mobile station crosses from one cell to another. These timing adjustments can be small in networks

where the base station clocks are partially or substantially synchronised.

As the base station clock contains some degree of instability and inaccuracy, of the order to a fraction of a part per million, the mobile station clock register 323 value wanders in relation to the GPS timing and thus over time becomes sufficiently desynchronised to produce inaccurate location estimations. Furthermore the ability of the mobile station 5 to receive and demodulate the GPS signals rapidly decreases as the mobile station timing and the GPS satellite timing diverge. This ability is reflected in the loss of acquisition sensitivity of GPS signals.

Thus at intervals the timing system refreshes the mobile station timing so that it is substantially resynchronised to the GPS satellite timing.

This refresh is carried out by the timing estimator 325 using processes as described earlier for initially fixing the mobile station timing to the GPS satellite timing. The clock register 323 is then updated with the substantially synchronised value from the timing estimator 325.

The mobile station then returns to the previous stage of maintaining the timing using the timing information from the cellular base station 3 or from the cellular reference clock, and awaiting the next refresh step, or until the mobile station is restarted or switched off.

The refresh step in one embodiment is triggered after a predetermined time period since the last refresh. The predetermined time period is known as a refresh interval.

The refresh step in another embodiment is triggered when the mobile station 5 is detected to have moved from inside to outside of a building.

This outside trigger can be implemented in one embodiment by detecting when the mobile station has moved after a period of relative static nature. The outside trigger can also be implemented in another embodiment by monitoring the power of the received signals and triggering the outside trigger after a sudden increase in the received power - caused by the reduction in the shielding effect of the building.

Further embodiments of the present invention may trigger a timing refresh step after the mobile station passes between base stations more than a predetermined number of times where the number of times is one or more. In such an embodiment the motion of the mobile station also provides an indication that the mobile station is in the open, in other words not being used inside a building, and is therefore more likely be able to receive GPS signals of a sufficient strength and number to provide a quick and accurate timing synchronisation.

Further embodiments of the present invention may trigger a timing refresh step after the received strength or received number of GPS signals detected by the GPS receiver is greater than a desired threshold. In such a situation the opportunity of being able to acquire a timing value quickly and with a high degree of accuracy is worth the extra processing.

Further embodiments of the present invention may trigger a timing refresh step after a combination of at least one of the above trigger events.

With reference to figure 6 a second embodiment of the present invention is described. The mobile station 5 comprises an antenna 301, a GPS receiver element 351, a cellular transceiver element 353 and interconnects 357, 359, and 361.

The antenna 301 is connected to the GPS receiver element 351, via the interconnect 357. The GPS receiver element is connected to the cellular transceiver element 353 via the interconnects 359 and 361. In one embodiment of the present invention the interconnect 359 passes signals between the GPS receiver element 351 and the cellular transceiver element 353, and the interconnect 361 passes signals between the cellular transceiver element 353 and the GPS receiver element 351.

The GPS receiver element comprises a GPS receiver 303, a GPS demodulator 313 and a timing estimator 325. The GPS receiver 303 has an input connected to the interconnect 357 and an output connected to the GPS demodulator 313 input. The GPS demodulator 313 output is connected to a first input of the timing estimator 325. The timing estimator has a first input/output connected to the interconnect 359 and a second input/output connected to the interconnect 361.

The GPS receiver receives signals from the antenna 301 via the interconnect 357. The GPS receiver 303 filters the received spectrum to output a signal to the GPS demodulator 313. The GPS demodulator 313 then performs demodulation on

the GPS signals to extract the timing data and the information data stored in the GPS signal. This timing and information data is then passed to the timing estimator 325. The timing estimator passes and is capable of receiving information from the cellular transceiver element 353.

The cellular transceiver element 353 comprises a location estimator 319, a clock register 323 and an interconnect 363. The interconnect 363 connects the location estimator 319 and the clock register 355. The location estimator is further connected via the interconnect 359 to the timing estimator 325 in the GPS receiver element 351. The clock register is connected is also further connected to the timing estimator 325 in the GPS receiver element 351 but via the interconnect 361.

This embodiment of the present invention therefore differs from the first embodiment of the present invention in that the GPS demodulation and timing estimation functions are not embedded within the cellular transceiver system and the cellular transceiver system is therefore provided with demodulated timing and data signals. Furthermore the location estimator 319 is capable of writing to and reading from the clock register 323.

In all other respects the second embodiment of the present invention functions in a manner similar to the earlier described embodiment. The timing synchronisation embodiments having the three main steps: synchronising using GPS synchronisation; synchronising using cellular synchronisation; and refreshing synchronisation. Furthermore each of these steps are implemented using processes described previously.

With respect to figure 7 a further embodiment of the present invention is shown. The mobile station 5 comprises a cellular antenna 601, a cellular transceiver 603, a cellular clock 605, a GPS receiver, a GPS antenna 621 and a timing processor.

The cellular antenna 601 is connected to the cellular transceiver. The cellular transceiver is further connected to the timing processor 607. The cellular clock 605 is connected to the cellular transceiver and the timing processor 607. The timing processor is further connected to the GPS receiver 619. The GPS receiver is connected to the GPS antenna 621.

The timing processor 607 further comprises a cellular processor 609, a cellular timing control 617, a frame/symbol timer 615, a GPS/cellular time correlator 611 and a GPS processor 613.

The cellular processor 609 is connected to the cellular timing control. The cellular processor is further connected to the frame/symbol timer 615. The cellular processor 609 is further connected to the cellular transceiver 603. Furthermore the cellular processor 609 is connected to the GPS/cellular time correlator 611. The cellular timing control 617 is connected to the cellular clock 605 via a cellular control interconnect 653. The frame/symbol timer 615 is connected to the GPS/cellular time correlator 611. The GPS/cellular time correlator 611 is further connected to the GPS processor 613. The GPS processor 613 is connected to the GPS receiver 619.

In order to provide more detail on the third embodiment of the present invention we shall the method of operation of the embodiment with reference to figure 8.

In the first step 801 the mobile station 5 is started or rebooted.

In the following step 803 the mobile station acquires the GPS time. In the third embodiment of the present invention the GPS receiver 619 receives the GPS signals. These GPS signals are passed to the GPS processor 613. The GPS processor uses the received bit data and the gold code data in order to acquire the GPS time using the methods as described previously. This GPS time is then passed to the GPS/cellular time correlator 611.

In the following step the GPS/cellular time correlator 611 compares the acquired time from the GPS processor to the cellular time provided to the timing processor 607 from the cellular clock. Thus the GPS time t1 is referenced to a specific cellular time defined as HF:SF:F:Sym:SS. With reference to the European GSM standard HF is the number of the hyper frame, which is made up of 2048 super frames (SF). Each super frame is made up of 1326 frames (F). Each frame is made up of 8 symbols (Sym). Each symbol is made up of 2 sub-slots (SS).

In the following step 807, the cellular processor 609 stores the GPS time referenced against the cellular time. In some embodiments of the present invention the values are stored in a memory such as a random access memory (RAM) or a register (not shown).

The mobile station then passes to the next step 809. The next step monitors whether a position fix is required. If a position fix is required then the method passes to step 811. If a position fix is not required the method passes to step 823.

During the time from when the GPS time was acquired and either step 811 or step 823, the cellular transceiver 603 has been receiving and passing cellular event data to the cellular processor. This cellular event data has a well-known and highly accurate time interval. An example of such a cellular event is a start of a frame. This cellular event data is passed to the cellular timing control 617 and the frame/symbol timer 615. The cellular timing control 617 uses this data in order to control the cellular timer 605. The frame/symbol timer 615 keeps a count of how many of these cellular events have occurred.

If a position fix is required the step 811 describes when the cellular processor reads the current cellular time from the frame/symbol timer 615.

Following step 811, step 813 describes when the cellular processor 609 calculates the elapsed cellular time (Tdelta) between the present cellular time and the cellular time at which the acquired GPS time was stored.

Following step 813, step 815 occurs as the cellular processor 609 adds the elapsed cellular time (Tdelta) to the stored acquired GPS time to get the current GPS time. This information is then passed to the GPS processor 613.

In the step following step 815, step 817 describes when the GPS processor 613 calculates a positional fix using the current GPS time and the current received signals passed from the GPS receiver.

Following step 817, the step 819 occurs when the GPS processor checks to see if the positional fix has been successful. If the fix has not been successful the method returns to step 809, where a further attempt of obtaining a positional fix can be made.

If the fix is successful the method passes to step 821 where the GPS processor returns the positional fix to the process or device within the mobile station 5 that requested the positional fix (not shown). The method then passes back to the step 805, where the current GPS time is referenced to the current cellular time.

When a positional fix is not required the step 823 is carried out. The step 823 occurs when the cellular processor reads the current cellular time from the frame/symbol timer 615.

Following step 823, step 825 describes when the cellular processor 609 calculates the elapsed cellular time (Tdelta) between the present cellular time and the cellular time at which the acquired GPS time was stored.

Following step 825, step 827 occurs as the cellular processor 609 adds the elapsed cellular time (Tdelta) to the stored acquired GPS time to get the current GPS time. This information is then passed to the GPS processor 613.

Following step 827, in step 831 the GPS processor determines if the error in the value of the current GPS time is greater than an acceptable threshold.

If the error in the value of the current GPS time is greater than an acceptable threshold then the method is reset back to step 801 whereby there is a re-acquisition of the GPS time.

If the error in the value of the current GPS time is less than an acceptable threshold then the method is passed back to step 809, where it checks to see if a position fix request has been received.

In further embodiments of the present invention rather than in step 831, as described above, the threshold event is the error value of the calculated current GPS time, the threshold event can be any of those described earlier. Thus the threshold event which causes a refresh or restart step back to step 801 may be the elapsed time (Tdelta), or the detection of movement of the mobile station 5 after a period of relative static nature, or the power of the received signals, or the detection of a number of times where the mobile station passes between base stations.

Further embodiments of the present invention may trigger a timing refresh step after a combination of at least one of the above trigger events.

Claims

1. A GPS device comprising:

a first circuit arranged to receive at least one first signal and arranged to output first timing information dependent on said first signal;

a second circuit arranged to receive at least one second signal and arranged to output second timing information dependent of said second signal; and

a third circuit arranged to determine timing information of said device, said third circuit arranged to receive at least one of said first and second timing information, and further arranged to produce third timing information dependent on at least one of said first and second signals,

wherein said third circuit further is arranged to produce a location estimate dependent on said first and third timing information; and

wherein said third timing information is initially synchronised to said first timing information and maintained substantially synchronised to said at least one first signal using said second timing information.

2. A device claimed in claim 1 wherein said first signal comprises a Global Positioning Satellite system signal.

3. A device as claimed in claims 1 or 2, wherein said second signal comprises a cellular network control or communications signal.

4. A device as claimed in claims 1 to 3, wherein said first timing information comprises at least one of:

a demodulated Global Positioning Satellite system time;

at least one Global Positioning Satellite system pseudo-range;

a demodulated Global Positioning Satellite system timing data word.

5. A device as claimed in claims 1 to 4, wherein said second timing information comprises at least one of:

cellular network base station symbol timing;

cellular network base station frame timing.

6. A device as claimed in claims 1 to 5, wherein said first circuit comprises a Global Positioning Satellite receiver.

7. A device as claimed in claims 1 to 6, wherein said second circuit comprises a cellular network receiver.

8. A device as claimed in any previous claim, wherein said third circuit comprises:

a GPS demodulator;

a timing estimator;

a location estimator; and

a clock register.

9. A device as claimed in claim 6, wherein said first circuit further comprises:

a GPS demodulator; and

a timing estimator.

10. A device as claimed in claim 9, wherein said third circuit comprises:

a location estimator and a clock register.

11. A device as claimed in any previous claim, wherein said third circuit comprises a cellular reference clock and wherein said third timing information is further maintained substantially synchronised to said at least one first signal using said cellular reference clock.

12. A device as claimed in any previous claim, wherein said second and third circuit is implemented in a single circuit.

13. A device as claimed in any previous claim, wherein said device further comprises a threshold circuit arranged to further substantially synchronise said third timing information to said at least one first signal dependent on a threshold event.

14. A device as claimed in claim 13, wherein said threshold circuit is arranged to further substantially synchronise said third timing information using said first timing information.

15. A device as claimed in claims 13 or 14, wherein said threshold event comprises at least one of:

a time period;

a movement of said device out of a building;

a movement of said device following a period of relative static nature;

a determined number of base station handovers;

a received first signal strength threshold;

a number of received first signals.

16. An integrated circuit comprising a GPS device as claimed in any previous claim.

17. A device as claimed in claim 8 wherein said clock register comprises random access memory.

18. A method for determining the position of a device using GPS comprising:

receiving at least one first signal;

producing first timing information dependent on said at least one first signal;

receiving at least one second signal;

producing second timing information dependent on said at least one second signal;

producing third timing information dependent on said at least one of said first and second timing information;

initially synchronising said third timing information to said first signal and maintaining synchronisation to said first signal using said second timing information, and

determining a location of said device dependent on said first timing information and said third timing information, wherein said determining step comprises the step of calculating a difference between said third timing information and said first timing information to determine location estimates.

19. A method as claimed in claim 18, wherein said step of receiving at least one first signal comprises;

receiving at least four GPS signals.

20. A method as claimed in claim 19, wherein said step of producing at least one first timing information further comprises;

processing said at least four received GPS signals to determine at least four GPS timing signals;

processing said at least four GPS timing signals to produce a true GPS timing signal.

21. A method as claimed in claim 18, wherein said step of receiving at least one second signal comprises;

receiving at least one communications or control signal from a wireless cellular communications system base station.

22. A method as claimed in claims 18 to 21, wherein said step of producing said third timing information comprises a further step of triggering a threshold circuit arranged to further substantially synchronise said third timing information to said at least one first signal dependent on a threshold event.

23. A method as claimed in claim 22, wherein said further step of triggering said threshold circuit is arranged to further substantially synchronise said third timing information using said first timing information.

24. A method as claimed in claims 22 and 23, wherein said step of triggering said threshold circuit further comprised the detection of a threshold event comprising at least one of:

a time period;

a movement of said device out of a building;

a movement of said device following a period of relative static nature;

a determined number of base station handovers;

a received first signal strength threshold;

a number of received first signals.

ABSTRACT

A GPS Device

A GPS device comprising: a first circuit arranged to receive at least one first signal and arranged to output first timing information dependent on the first signal; a second circuit arranged to receive at least one second signal and arranged to output second timing information dependent of the second signal; and a third circuit arranged to determine timing information of the device. The third circuit is arranged to receive at least one of the first and second timing information, and further arranged to produce third timing information dependent on at least one of the first and second signals. The third circuit further is arranged to produce a location estimate dependent on the first and third timing information. The third timing information is initially synchronised to the first timing information and maintained substantially synchronised to the at least one first signal using the second timing information.

fig 1

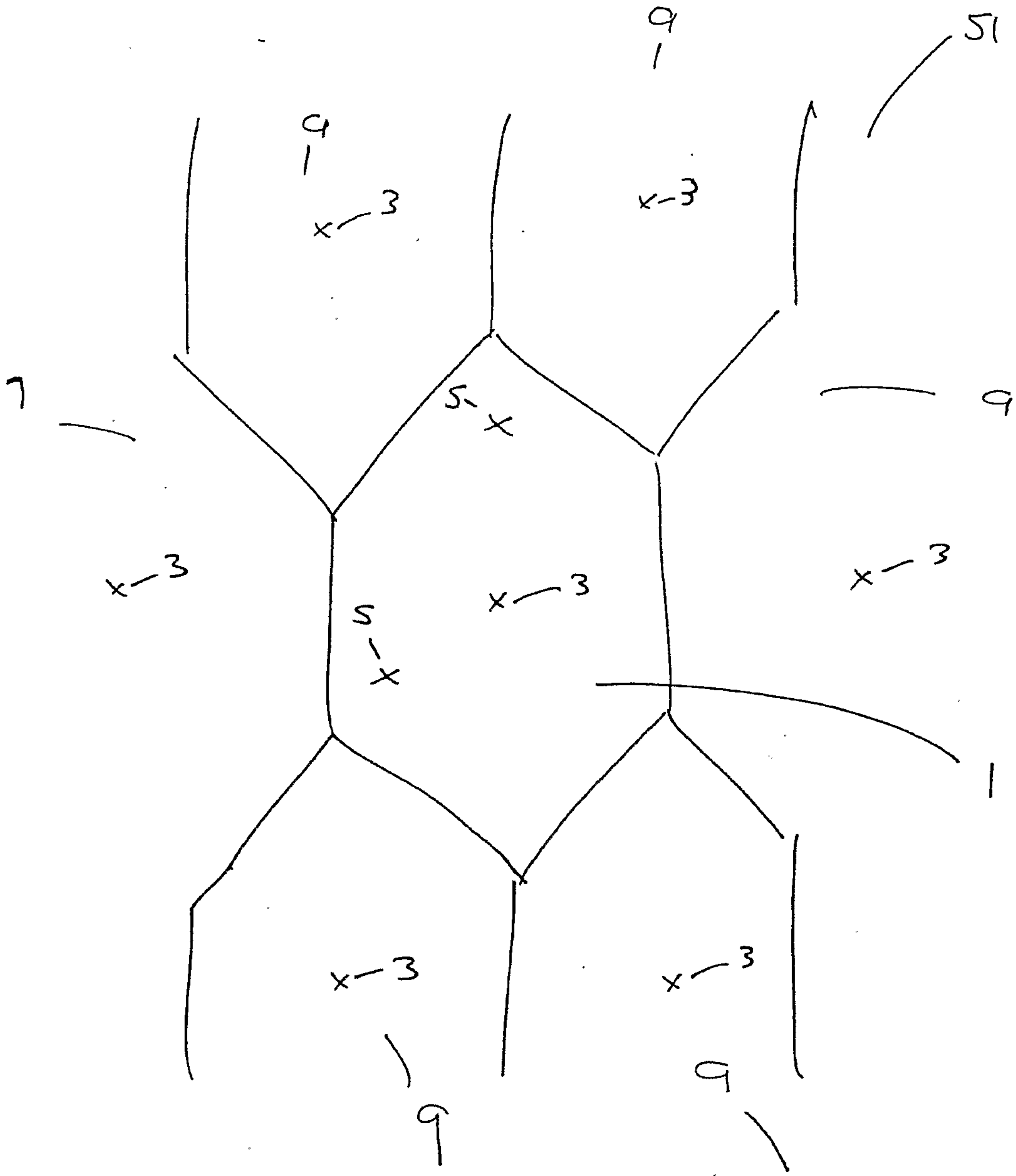


fig 2

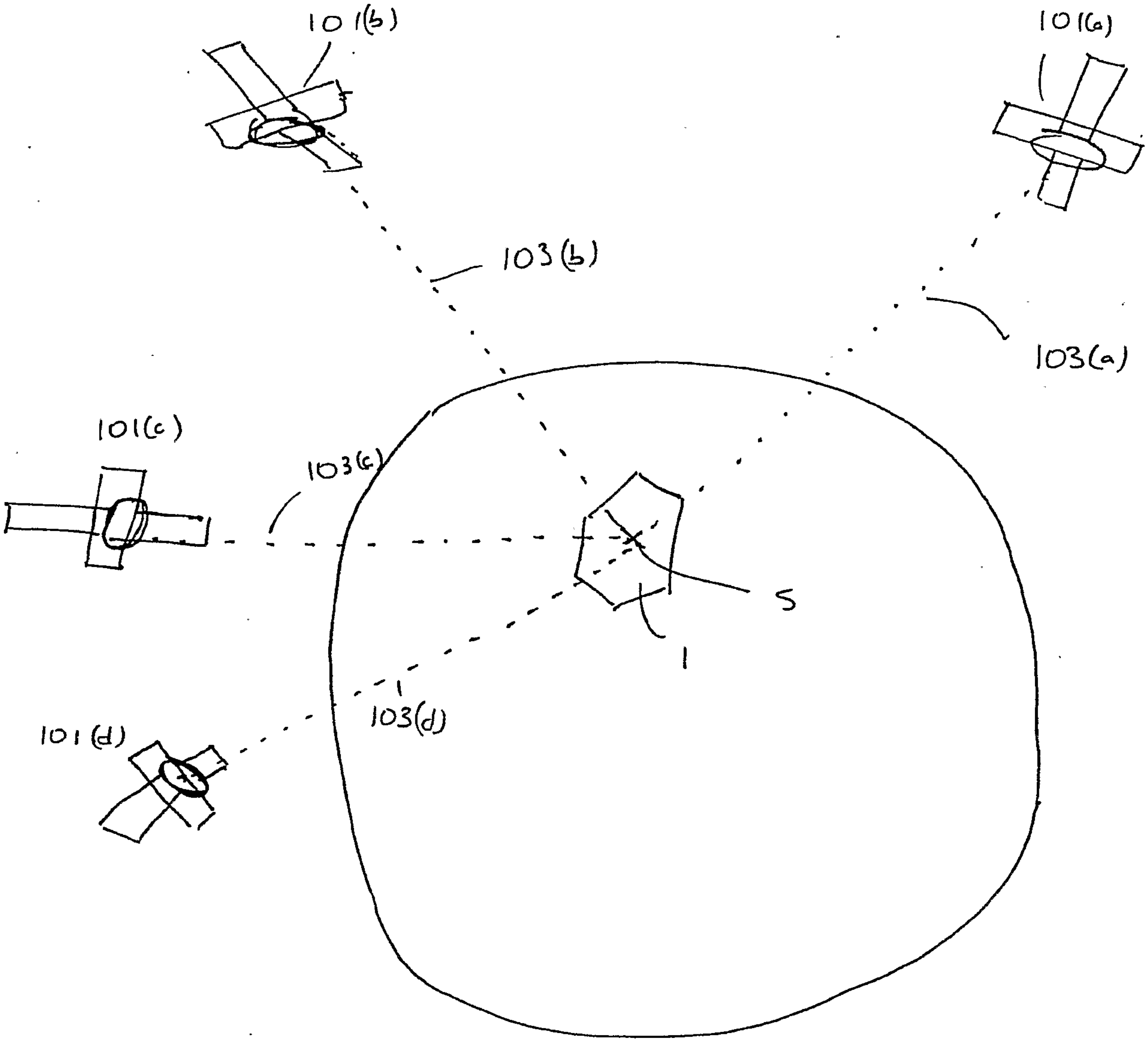


fig 3

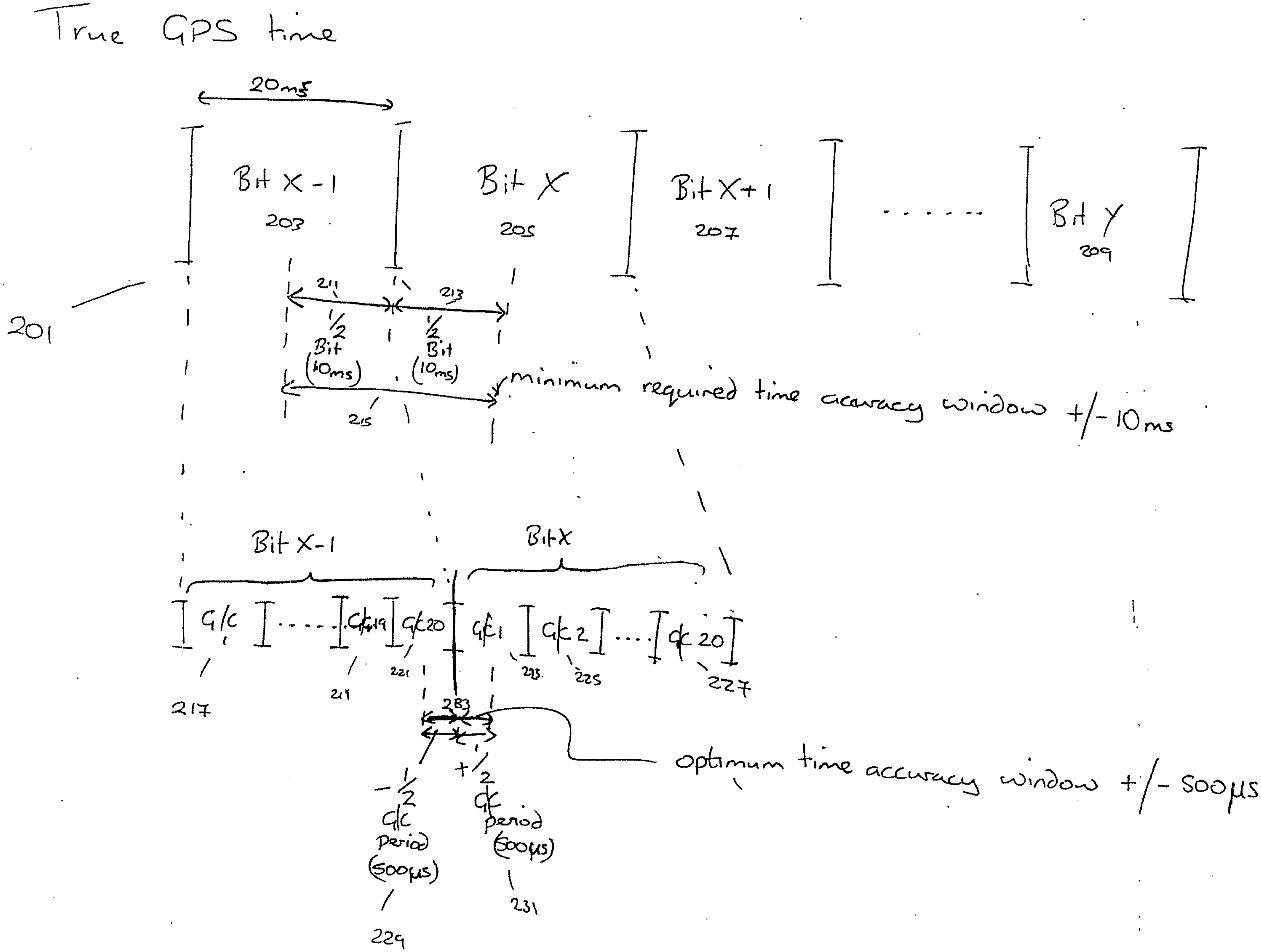
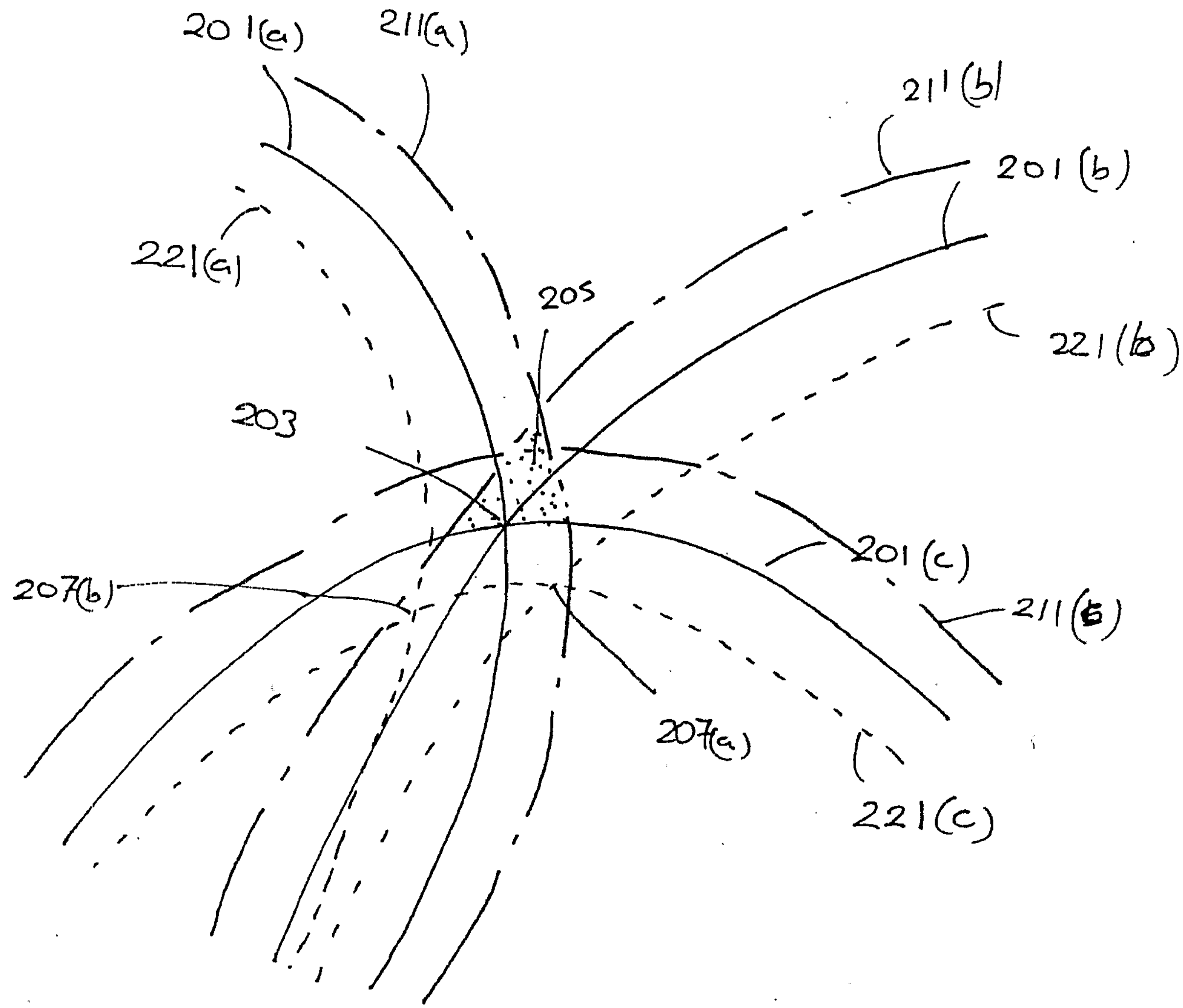
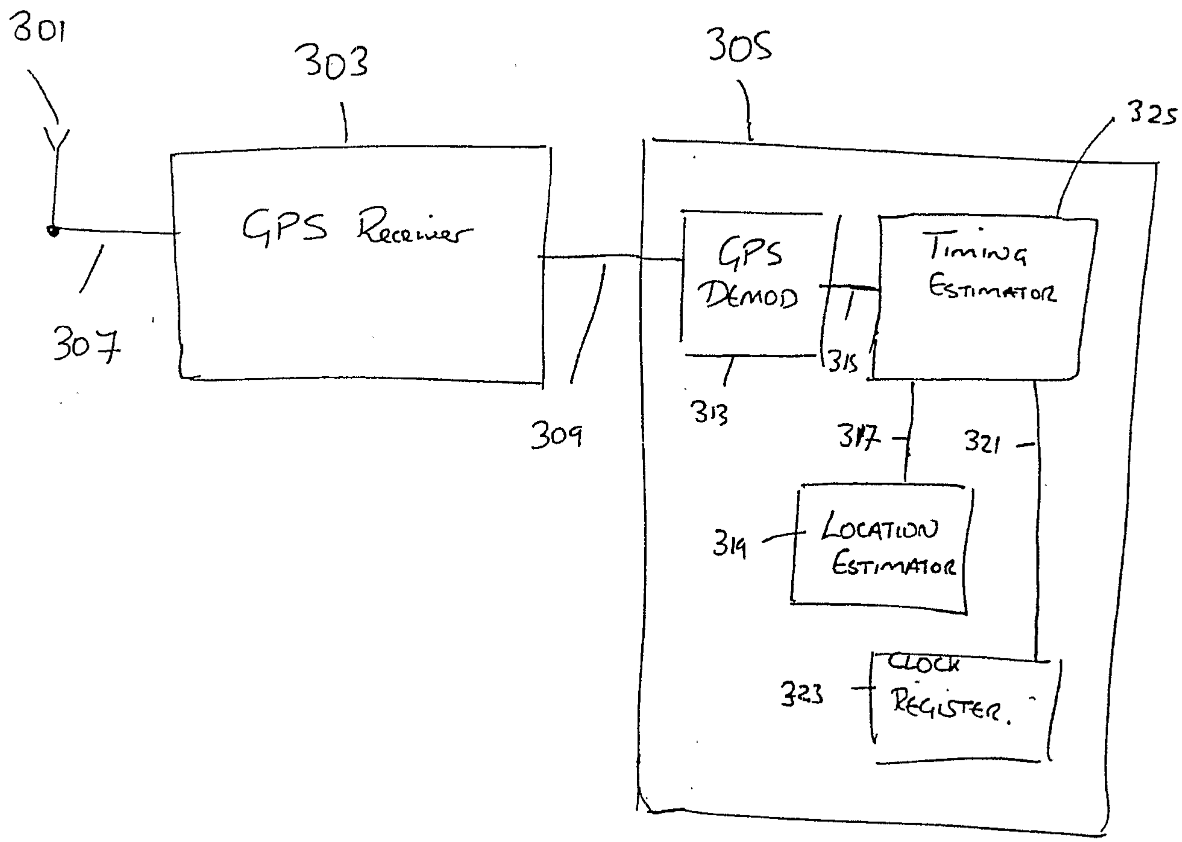

True GPS time
20ms
Bit X-1
203
Bit X
205
Bit X+1
207
Bit Y
209
201
211
213
1/2 Bit (10ms)
1/2 Bit (10ms)
215
minimum required time accuracy window +/- 10ms
Bit X-1
Bit X
G/C
C/A 19
C/A 20
C/A 1
C/A 2
C/A 20
217
219
221
223
225
227
233
optimum time accuracy window +/- 500µs
- 1/2 C/A period (500µs)
+ 1/2 C/A period (500µs)
229
231

fig 4



201(a)
211(a)
221(a)
211(b)
201(b)
221(b)
205
203
201(c)
211(c)
207(b)
207(a)
221(c)

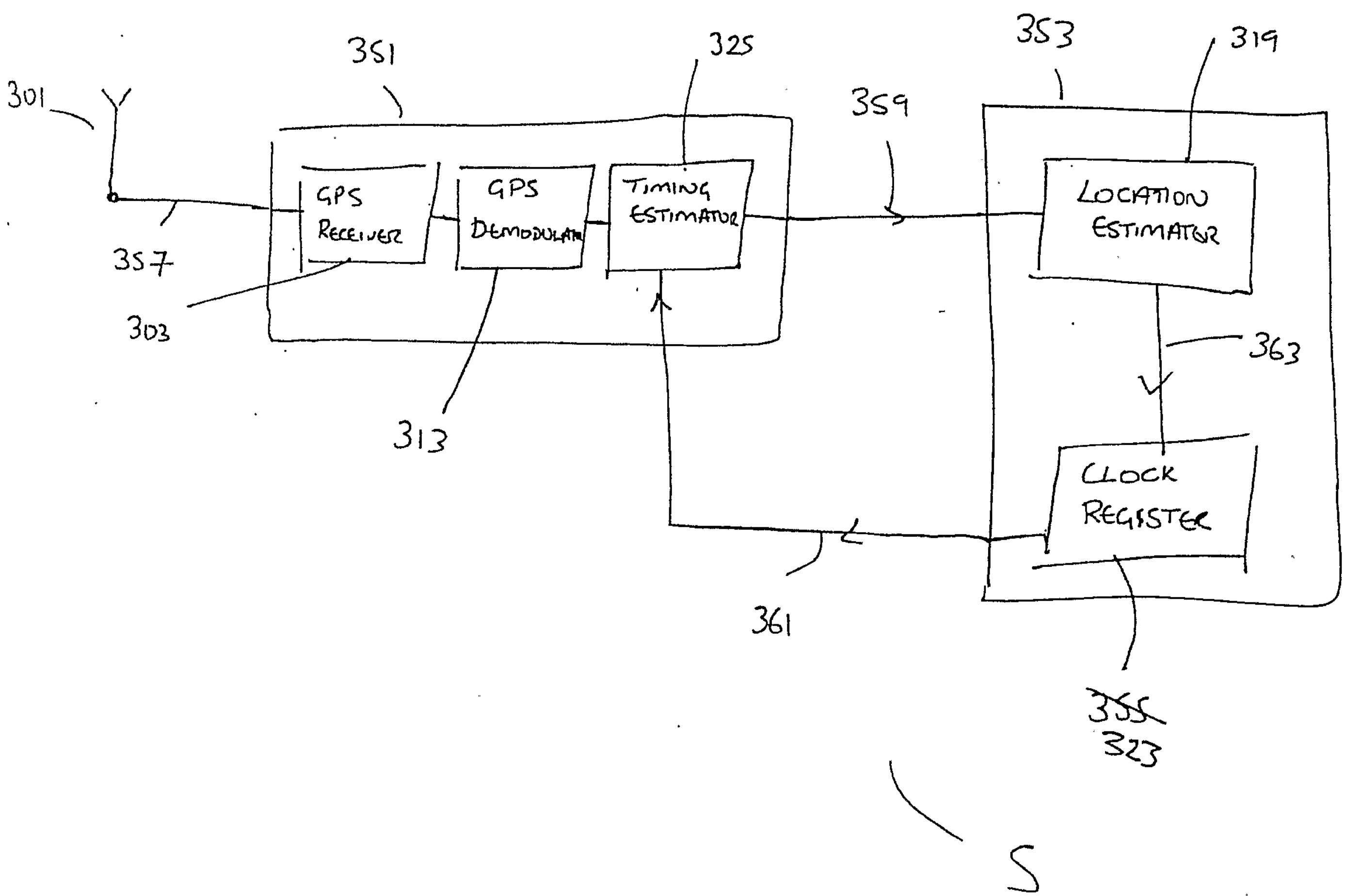
fig 5



301
303
GPS Receiver
307
309
305
325
GPS DEMOD
Timing Estimator
313
315
317
321
319
Location Estimator
323
Clock Register.

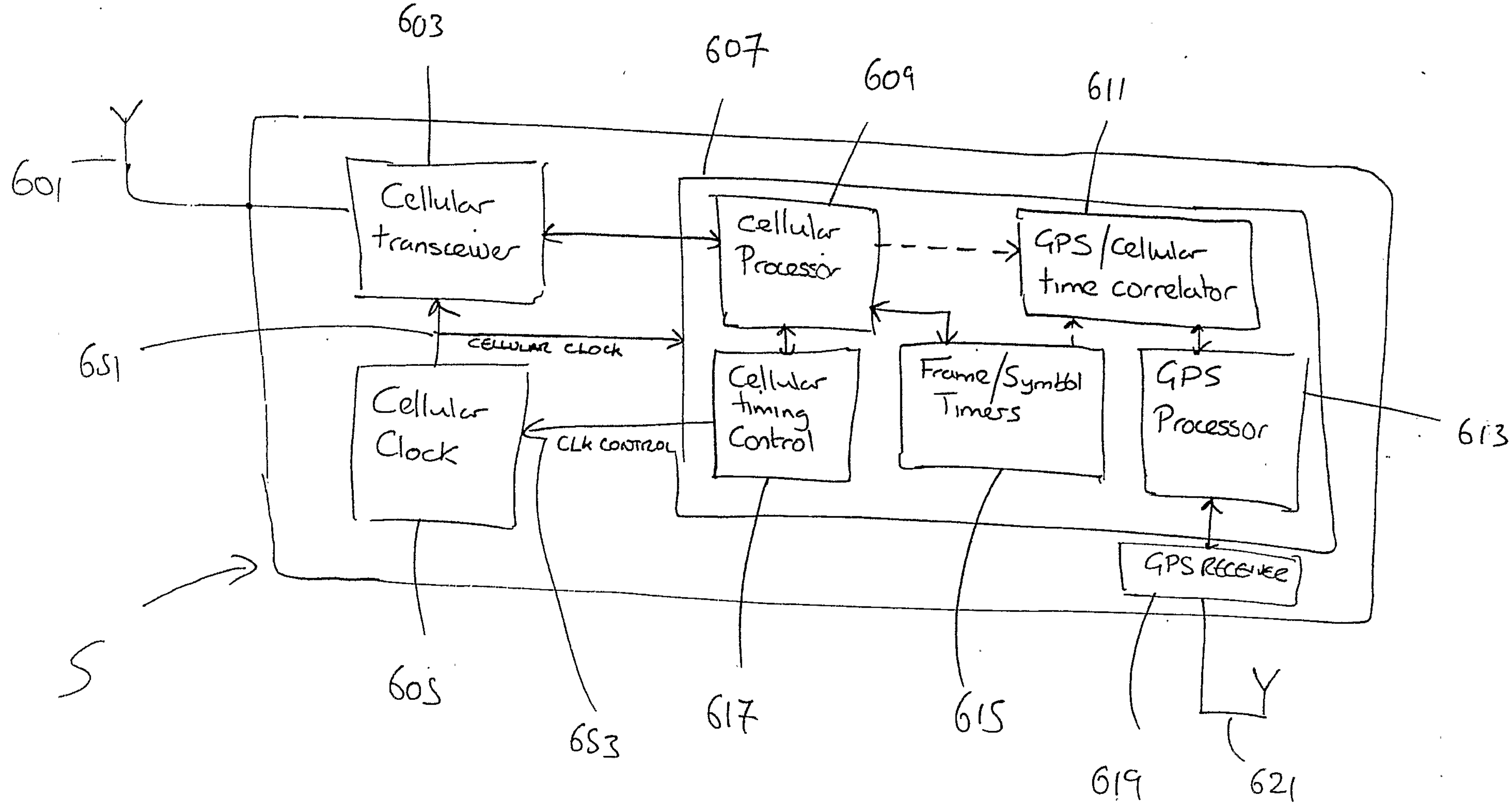
5

fig 6



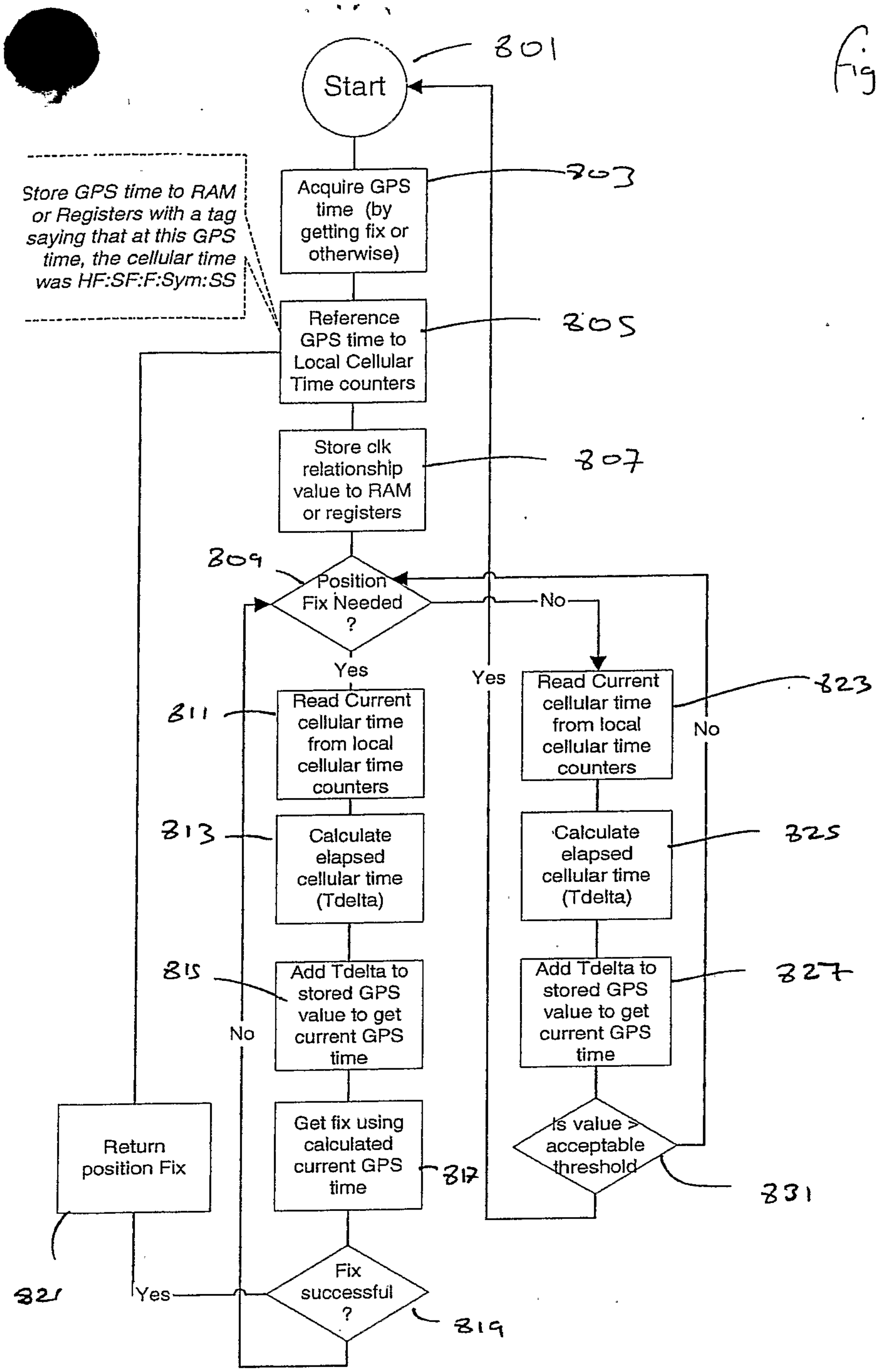
301
351
325
353
319
359
GPS Receiver
GPS Demodulator
Timing Estimator
Location Estimator
357
303
313
363
Clock Register
361
~~355~~
323
5

fig 7



603
607
609
611
601
Cellular transceiver
Cellular Processor
GPS/Cellular time correlator
651
CELLULAR CLOCK
Cellular Clock
Cellular timing Control
Frame/Symbol Timers
GPS Processor
613
CLK CONTROL
GPS RECEIVER
5
605
653
617
615
619
621

Fig 8



801
Start
803
Acquire GPS time (by getting fix or otherwise)
Store GPS time to RAM or Registers with a tag saying that at this GPS time, the cellular time was HF:SF:F:Sym:SS
805
Reference GPS time to Local Cellular Time counters
807
Store clk relationship value to RAM or registers
809
Position Fix Needed ?
No
Yes
811
Read Current cellular time from local cellular time counters
813
Calculate elapsed cellular time (Tdelta)
815
Add Tdelta to stored GPS value to get current GPS time
No
Get fix using calculated current GPS time
817
Fix successful ?
819
Yes
Return position Fix
821
Yes
823
Read Current cellular time from local cellular time counters
No
825
Calculate elapsed cellular time (Tdelta)
827
Add Tdelta to stored GPS value to get current GPS time
Is value > acceptable threshold
831

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